Dr. Ronald Azuma
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Ronald Azuma is a Research Staff Member at HRL Laboratories, the central research facility for Hughes Electronics and Raytheon Systems Corporation. He received a B.S. in Electrical Engineering / Computer Science from UC Berkeley in 1988, and an M.S. and Ph.D. in Computer Science from the University of North Carolina at Chapel Hill in 1990 and 1995, respectively. He joined HRL Laboratories in 1995. His research projects are in the areas of 3-D interactive computer graphics, Augmented Reality, Virtual Environments, and human-computer interaction.

Dr. Azuma has published several papers in the area of Augmented Reality, including a well-known survey paper and two SIGGRAPH papers. For his dissertation research he built a system that dramatically reduced registration errors in an optical see-through HMD system. He served on the program committee for the First International Workshop on Augmented Reality and gave an invited talk at the First International Symposium on Mixed Reality. He will give another invited talk at the 5th Eurographics Workshop on Virtual Environments (with a focus on Augmented Reality). He also taught two courses in this area at SIGGRAPH '95 and '97.

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Improving the Accuracy of Outdoor Augmented Reality Systems

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Potential military applications of Augmented Reality

- Friend/foe identification
- Navigation aids
- Identify the invisible
  - Minefields
  - Sniper in a window
  - etc.
- Share spatially-located information with widely-dispersed team members

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The Tracking Problem

- Registration: accurate alignment of virtual over real.
- Without accurate registration, most military applications will fail.
- GRIDS team attacking this problem
  - Geospatial Registration of Information for Dismounted Soldiers
  - HRL, USC, UNC-CH, Raytheon

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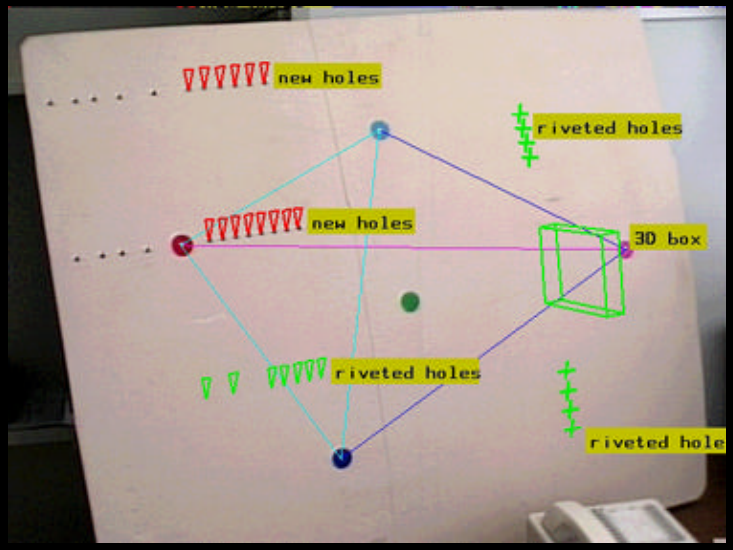
Challenge of Tracking Outdoors

- **Going outdoors is difficult!**
  - **Fewer resources (computation, power, etc.)**
  - **Greater range of operating conditions**
  - **Little control over environment**



Courtesy Ulrich Neumann, USC IMSC

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No Single Tracking Technology is Sufficient

- GPS
  - Position only. Line of sight. Jammable.
- Inertial
  - Sourceless but drifts. Cost and weight.
- Active Sources
  - Requires modifying environment, restricts range to local area modified.
- Passive Optical (video tracking)
  - Brittle and computationally-intensive

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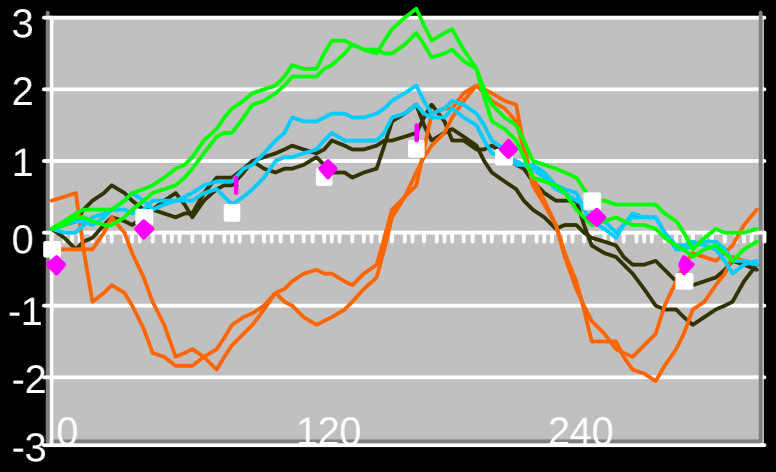
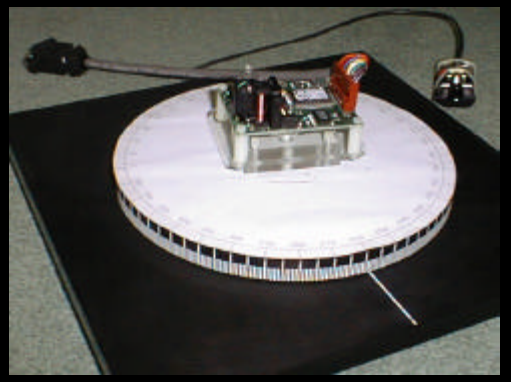
COTS Trackers are Not Enough!

- Compass/tilt sensor has large static and dynamic distortions. 2-4° at best.
- Relatively consistent within half-hour
- Autocalibration for changing distortions

Compass error, in deg.



Turntable heading, in deg.



Non-ferrous turntable

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GRIDS Approach: Hybrid Tracking

- **Hybrid tracking: combine multiple sensors to cover weaknesses**
- **Novel inertial-optical hybrids**
- **Initial base system (HRL)**
  - **Assume distant objects (DGPS sufficient)**
  - **Tackle largest error (latency)**
  - **Compass / tilt sensor / gyros hybrid**
  - ***Stabilize* outputs, *calibrate* distortions**

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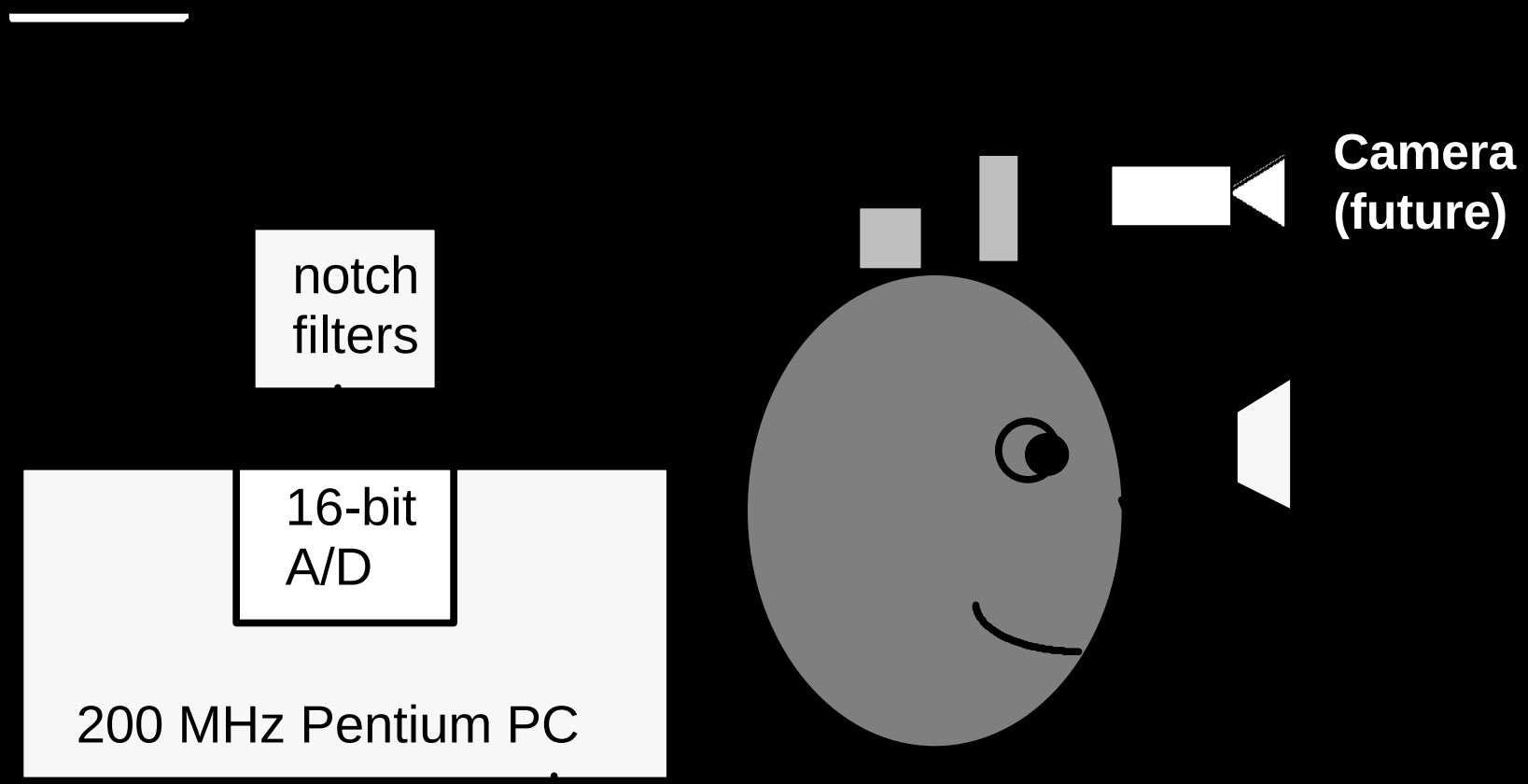
Base System Results

- First outdoor motion-stabilized AR
- Closest registration of known real-time *outdoor* AR systems
- Unusable without stabilization and calibrations
- 60 Hz update rate
- Close registration
  - but not perfect!

Base System Dataflow



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Visual feature tracking (1)

- USC: Ulrich Neumann and Suya You
- Hybrid of 2-D video + inertial tracking
- Inertial gives initial guess (high freq.)
- Video features correct drift (low freq.)

USC UNIVERSITY OF SOUTHERN CALIFORNIA

imsc

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Visual feature tracking (2)

- Improves registration to a few pixels
- Not running in real time yet
- 3-D solution (orientation only)

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Video

- **Run the video!**

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Future Work

- Interface design / Visualization
- Further registration refinements
  - Visual corrections in real time
  - Landmark-based refinement
- Night Vision System
- Dealing with position (beyond GPS)
  - Additional sensors
  - Full 6-D indoor/outdoor tracking (UNC-CH)

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Path Toward Ultimate Deployment

- **Mockup of sensors and display on Land Warrior helmet. Sensor & display = 0.3 lbs.**
- **Display bright enough to see in sunlight. Projected MEMS sensors.**

Raytheon